GhanaVeg Sector Reports

GhanaVeg

Strategies to support the greenhouse horticulture sector in Ghana

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Strategies to support the greenhouse horticulture sector in Ghana

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Abstract (English)

Protected cultivation in Ghana is relatively small, though public and private interest is rapidly increasing. This report presents a quick scan of the sector, with a focus on business opportunities. From a value chain perspective, inadequate access to inputs, low production levels, poor storage facilities and low product quality are the main limitations. Key factors to improve the situation are: a) a country-wide seed supply system that makes available high quality cultivars, b) the availability of biological control agents, c) a greenhouse design that is suitable for the local, hot climate, d) a healthy growing medium, and e) well-trained management and staff. Business opportunities are: a) greenhouses adapted to the local climate, greenhouse equipment, solar energy, sensors and data loggers, and a local industry fabricating and maintaining goods, b) variety trials and hybrid varieties, and c) integrated pest management and biological control.

Abstract (Dutch)

De bedekte teelt in Ghana is relatief klein, als neemt de publieke en private belangstelling snel toe. Dit verslag geeft een quick scan van de sector waarbij het ingaat op de marktkansen. Vanuit het ketenperspectief zijn slechte toegang tot inputs, lage productieniveaus, slechte opslagmogelijkheden en lage product-kwaliteit de belangrijkste beperkingen. De belangrijkste factoren om de situatie te verbeteren zijn a) een landelijke zaadleverantiesysteem dat goede cultivars op de markt brengt, b) de beschikbaarheid van biologische bestrijdingsmiddelen, c) een kasontwerp dat geschikt is voor het plaatselijke hete klimaat, d) een gezond groeimedium, en e) goede training van management en staf. Marktkansen zijn: a) kassen die zijn aangepast aan het plaatselijke klimaat, kasuitrusting, zonne-energie, sensoren en dataloggers, en een plaatselijke industrie de materialen maakt en onderhoudt, b) rassenproeven en hybride variëteiten, en c) geïntegreerde en biologische gewasbescherming.

Keywords: GhanaVeg, Ghana, greenhouse horticulture, business opportunities

Report GTB-1353

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1. Summary

Protected cultivation in Ghana is relatively small, though public and private interest is rapidly increasing. There are various challenges with the supply-chain, the production phase and the post-harvest value chain. This report presents a quick scan of the sector, with a focus on business opportunities. From a value chain perspective, inadequate access to inputs, low production levels, poor storage facilities and low product quality are the main limitations.

Greenhouse production systems in a proper functioning value chain can contribute to higher productions and better product quality. Key elements are:

a) A country-wide seed supply system that makes available high quality cultivars.

b) The availability of biological control agents.

c) A greenhouse design that is suitable for the local, hot climate. Temperatures in Ghana are high, although the regions around Kumasi and Wenchi are a little cooler. Relative air humidity decreases from south to north, and the country knows both rainy and dry seasons. Cooling must be through natural ventilation, as mechanic cooling is too expensive. Growers can choose between net houses and plastic houses with fixed window openings. Flexible window openings are not required as cold periods do not occur. If electricity is problematic, fertigation can be gravity-based; if electricity is available, then an automated fertigation system can be installed. Good ventilation is essential, and therefore, top windows are required as otherwise the hot air can not leave the greenhouse. Screens are an option to manage radiation levels in case of specific crops.

d) A healthy growing medium. Regular soil is likely to be infested with soil-borne pathogens such as bacterial wilt.

e) Well-trained management and staff.

The same greenhouse concept can be used all over Ghana as the variation in climate conditions are not extreme, although the ventilation capacity may be adjusted to the local climate.

It should be possible to realize a well-producing greenhouse system with investments yielding benefits after the third year. If current investment costs are reduced, then at the current high market prices for e.g. tomatoes, investments could be even more beneficial. Reduction of greenhouse costs is quite well possible if local construction is realized, or if competing suppliers enter the market.

Business opportunities for the greenhouse sector are:

a) Greenhouses adapted to the local climate, greenhouse equipment, solar energy, sensors and data loggers. A local industry fabricating and maintaining goods.

b) Variety trials, hybrid varieties.

c) Integrated pest management, biological control.

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2. Background

2.1 The GhanaVeg Programme

The overall mission of the GhanaVeg programme is to establish "a sustainable and internationally competitive vegetable sector that contributes to inclusive economic growth and has the capacity to continuously innovate in terms of products and services". The programme focus is on:

1. Attracting and/or supporting frontrunner companies.
2. Support for (technical) innovation by the private sector.
3. Assist the sector with evidence-based information and facilitate greater collaboration.
4. Tomato, chilli peppers, bell peppers, onions, Asian vegetables, spices.
5. The commercial smallholder farmer, the small investor farmer, large-scale farming (with outgrowers).

As one of the fast-track activities to ensure speedy implementation, **a "quick scan" on greenhouse horticulture, also investigating business opportunities for the Dutch private sector** has been organized from the GhanaVeg Consultancy Fund.

In addition, it is proposed to provide, upon request, concrete advice to commercial stakeholders with regards to greenhouse design, management of the greenhouse system, etc. The precise form of requested support will depend on the needs of the commercial stakeholders and clearance by the Selection Committee. This should be organized through the Business Opportunity Fund.

2.2 A quick scan on greenhouse horticulture

The objectives of the mission 'Quick scan greenhouse horticulture in Ghana' were:

1. Identify basic conditions and options for the (further) development of greenhouse horticulture in the regions of Volta, Kumasi and Tamale in Ghana, in terms of
   - climate
   - greenhouse construction
   - greenhouse installation
   - management of climate, crop, fertigation (irrigation & fertilization), and pests and diseases
   - knowledge and knowledge systems.
2. Map the value chain of the main vegetables under protected conditions, analyse the cost and price development along the chain and identify the commercialization channels.
3. Identify business opportunities for the Dutch and Ghana's private sector that are based on low to medium-technology level greenhouses.

The assignment should result in informed knowledge on various alternatives for the development of greenhouse horticulture in regions of Volta, Kumasi and Tamale in Ghana, with regards to greenhouse technology, crop management, knowledge, value chains and business opportunities.

The mission was conducted by an interdisciplinary team of scientists from Wageningen UR, The Netherlands, and the Forest and Horticultural Crops Research Centre, Kade, Ghana. The team visited a number of locations in the vicinity of Accra, Kumasi and Tamale.

The adaptive greenhouse approach (see Annex 3) allows for an inventory of prerequisites that reduce the number of options for greenhouses in a specific biophysical and socio-economic setting. For example, greenhouses must have adequate cooling because of the warm climate in Ghana, and therefore designs with low ventilation capacity are not an option. Furthermore, the high levels of investments and operational costs required for active cooling on the basis of fossil energy implies that such greenhouse types do not need to be considered for Ghana. E.g., a recent study for greenhouse types in Mexico indicate that a high-tech greenhouse needs investments of approximately €200 m^{-2} and has variable costs of approximately €32 m^{-2} y^{-1} (Elings et al., 2014). In addition, such greenhouses require good maintenance and very high levels of knowledge. The common understanding of all stakeholders we met was that such greenhouses would not fit in the current Ghanaian situation because of the a combination of skills and investments required.

A more appropriate transition path simultaneously improves knowledge, technology, supply chains (input and maintenance), and post-harvest chains. Therefore, the mission should focus on low to medium levels of technology. Given the investments that are also needed for low-tech greenhouses, and given the fact that the pay-back period should be as short as possible, it was decided to focus on a restricted number of most profitable crops (e.g., tomato, cucumber, pepper). This further reduced the number of agri-chains to be assessed.

2.3 Acknowledgements

We gratefully acknowledge the support of the GhanaVeg office at IFDC in Accra, viz. Ms. Enam Gbekor and Mr. Hanson Arthur. We thank all those who made time for us to introduce us to Ghanaian horticulture, and DGIS as funding agency. ■

Mr. Maroun Kaddoun in his greenhouse at Akuse near Accra

3. Agro-ecological zones

3.1 Climate zones

Ghana has roughly three greenhouse areas, viz. Accra, Kade and Volta; Kumasi and Wenchi; and Tamale. It is often claimed that the Accra and Volta regions are hot and humid, whereas the Kumasi climate is a little cooler because of the slightly higher altitude of approximately 300 m. Tamale is known to be relatively dry.

Temperature. The influence of the nearby sea is noticeable in Accra through the relatively low night temperature of 24.5 °C (Table 1). The long-term average temperature in Accra is 28.0 °C. Kade is only a little cooler. The other locations, which are all inland, have lower minimum temperatures at night. Volta and Tamale stand out because of their relatively high maximum temperatures at daytime.

Relative air humidity. Humidity in Accra is relatively high all-year round, and shows a dip in Wenchi in the dry season. The dry season in Accra barely leads to a lower relative air humidity. Relative air humidity in Wenchi and especially Tamale are lower than elsewhere in Ghana.

Rainfall. Ghana (except the north) has two rainy seasons, viz. from April to July and from September to November. The rainy season in the north begins in April and lasts until September. Annual rainfall ranges from about 1,100 mm in the north to about 2,100 mm in the southeast.

- Accra has a major rainy season from March to July, and a minor rainy season from August to October. Total annual rainfall in Accra is lowest of all locations considered (891 mm $year^{-1}$).
- The Volta Region has two rainfall regimes in the year, the first from March to July and the second from mid-August to October. Our example site (Kpandu) has a relatively low annual rainfall – elsewhere in the Volta region it can reach 2100 mm.
- Kumasi averages around 1400 mm of rain per year and has two different rainy seasons, a longer rainy season from March through July and a shorter rainy season from September to November.
- Wenchi in the Brong Ahafo region also has a double rainfall pattern. Precipitation ranges from an average of 1000 mm in the northern part to 1400 mm in the southern part. The rainy season is between April and October with a short dry spell in August. The minor season is from September to October.

Table 1. *Some annual values of climate characters at a number of locations in Ghana*

Location	Period	Temperature (°C)			Relative air humidity (%)		Rainfall (mm $year^{-1}$)	Distinguishing characteristics (relative to other locations)
		min.	*av.*	*max.*	*15:00 hrs*	*6:00 hrs*		
Accra	2008–2012	24.5	28.0	31.3	66	89	891	high day & night temperature, low rainfall
Kade	2010–2014	23.7	28.4	33.1	66	92	1461	high day & night temperature, high rainfall
Kpandu (Volta)	2002–2011	22.6	27.6	32.6	64	92	1275	high day temperature
Kumasi	long-term	21.0	25.8	30.2	58	83	1484	low night temperature, high rainfall
Wenchi	1986–2011	20.9	26.5	29.8	38	80	1288	low night temperature, low relative air humidity
Tamale	long-term	22.5	28.1	33.3	44	47	1090	high day temperature, low relative air humidity

- The rainy season in the north, around Tamale, is monomodal (one rainy season) and starts from May to October with a peak in September. The dry period is from December to April/May. Also Tamale is relatively dry with an average annual precipitation of 1090 mm.

Detailed climate information is provided in Annex 4.

3.2 Growing seasons

The main growing season for open field vegetables is during the major and minor rainy periods. In the dry season only locations with irrigation are cultivated with vegetable crops, especially at the dam sites such as Vea and Tono in Navrongo or places near big rivers such as the White Volta in Pwalugu near Bolgatanga in the Upper East Region. Dry season vegetable production is also carried out at Akumadan irrigation dam site, as well as at other dam sites like Ashiaman and Dawenya. In places like Angloga, dry season production is done using water from underground dugouts mounted with water pumps. If irrigation is possible, then open field vegetable production during the dry season is very attractive as prices are higher (e.g., Tamale region).

Different strategies for protected cultivation are possible:

1. Grow two crops during the rainy season, and avoid growing a crop during the dry season, as indoor temperatures in the dry period can rise to very high levels (> 40 °C) that are detrimental to for example fruit set and development.

This strategy is followed by for example FreshFields in the Volta region, which produces in the period February–October. FreshFields nurses seeds in February and transplants in March for the major rainy season and sow seeds in August for the minor rainy season cultivation in greenhouses. Tomato and pepper are the main crops grown.

Relative air humidity is a likely problem in the rainy season, especially in the early morning. Ventilation offers only limited help as both indoor and outdoor air are very humid. Mechanical air circulation to dry the crop is recommended. Also Hikma Farms in Tamale follows this strategy. They sow in March for the April–June season, and sow in August for the September-October season.

2. Grow one or two crops during the dry season, if temperatures can be managed. The advantages are high market prices and low postharvest losses. The disadvantage is the risk that high temperatures cannot be avoided. A greenhouse with sufficient ventilation capacity in the top of the structure is required. Good crop transpiration (sufficient water supply!) adds a little to temperature reduction.

This strategy was followed by the African Boreholes Initiative at Wenchi, where temperatures are just a little lower than elsewhere in the country and where irrigation water is available. Their cultivation period is September–February. Amiran greenhouses were used at the African Boreholes Initiative, which were closed at the top, and which therefore had fairly high indoor temperatures.

Very high temperatures have a negative effect on the photosynthesis rate and consequently on growth, and on fruit set. Photosynthesis is actually relatively stable over a wide range of temperatures (up to 35 °C no substantial decrease for tomato (Qian et al., 2012). The sensitivity of fruit set processes is not well quantified, but high temperatures may lead to flower and fruit abortion.

3. FOHCREC, Kade grows heat tolerant varieties in the dry and hot period, with sowing in January and harvesting in May. FOHCREC also evaluates using different tomato varieties from seed companies in the major and minor rainy seasons. Tomatoes, cucumbers and cabbages are grown in rotation. FOHCREC uses ventilated greenhouses with chimneys or windows in the top which enables the hot air to leave the greenhouse and realizes a relatively low temperatures inside compared to the outside temperatures. The fans also help in drying leaves when humidity is high. There is a need for evaluation of more tomato varieties that are heat tolerant and will produce fruits in the hot periods. FOHCREC further investigates performance of tomatoes under different colour shades.

Opportunity

Greenhouses with good climate management that enable indoor production during (part of) the dry season when prices are high. This must be accompanied by irrigation water supply.

4. The value chain

Tomatoes and peppers are commonly regarded as two major vegetables for local consumption in Ghana. Unfortunately, many factors hinder the production of fresh vegetables in the country. The national demand for these crops has widely surpassed the capacity of Ghanaian farmers to produce on a steady, cost-effective and high-quality basis. As a result, figures demonstrate that yearly much money is spent on importing vegetables from neighbouring countries.

Aiming at overcoming the structural problems that affect the local vegetable industry (see Figure 3), local researchers and authorities believe that greenhouse technology could be instrumental in providing reliable and high quality fresh produce.

To understand how greenhouse technology can boost the local vegetable production, we adopt a value chain approach in which pre-production, greenhouse production technology and post-production issues are studied.

Figure 2 depicts a standard fresh produce chain in Ghana, with actors and their function in the chain. Note that the canvas depicted is one of the outputs of the workshop held with local stakeholders involved in the vegetable sector. The figure shows a generalized value chain model for consolidated and locally consumed vegetables; tomatoes and peppers.

A number of limitations/challenges arise for each step of the chain. Figure 3 presents a list of limitations by step according to the views of all stakeholders interviewed. Most frequently mentioned challenges were inadequate access to inputs, low level of production, poor storage facilities and low product quality. The above-described limitations should be taken into account when considering the feasibility of greenhouse technology under the Ghanaian conditions. What challenges related to the production of vegetables can greenhouse technology address in the near future (Figure 4)?

Adoption of greenhouse technology might bring about changes to Ghana's agricultural outlook in the coming years. Improvements in yield, quality of produce and a prolonged farming season are arguably the outcomes to be expected or pursued with this technology. However, prior to discussing what outputs can be achieved, attention must be paid to studying the existing state of affairs with respect to greenhouse technology in Ghana.

To examine the appropriateness of such technology, three thematic areas have been defined:

- **Pre-production aspects in Ghana:** this includes input suppliers (seeds and varieties) and climatic condition.
- **Greenhouse technology aspects:** Construction materials available, installation, crop protection agents, substrate, fertilizers, water, human resources, knowledge and energy.
- **Post-production:** transport and market of greenhouse produce.

Figure 1. *Value chain canvas, developed as an output of the workshop held with local stakeholders involved in the vegetable sector*

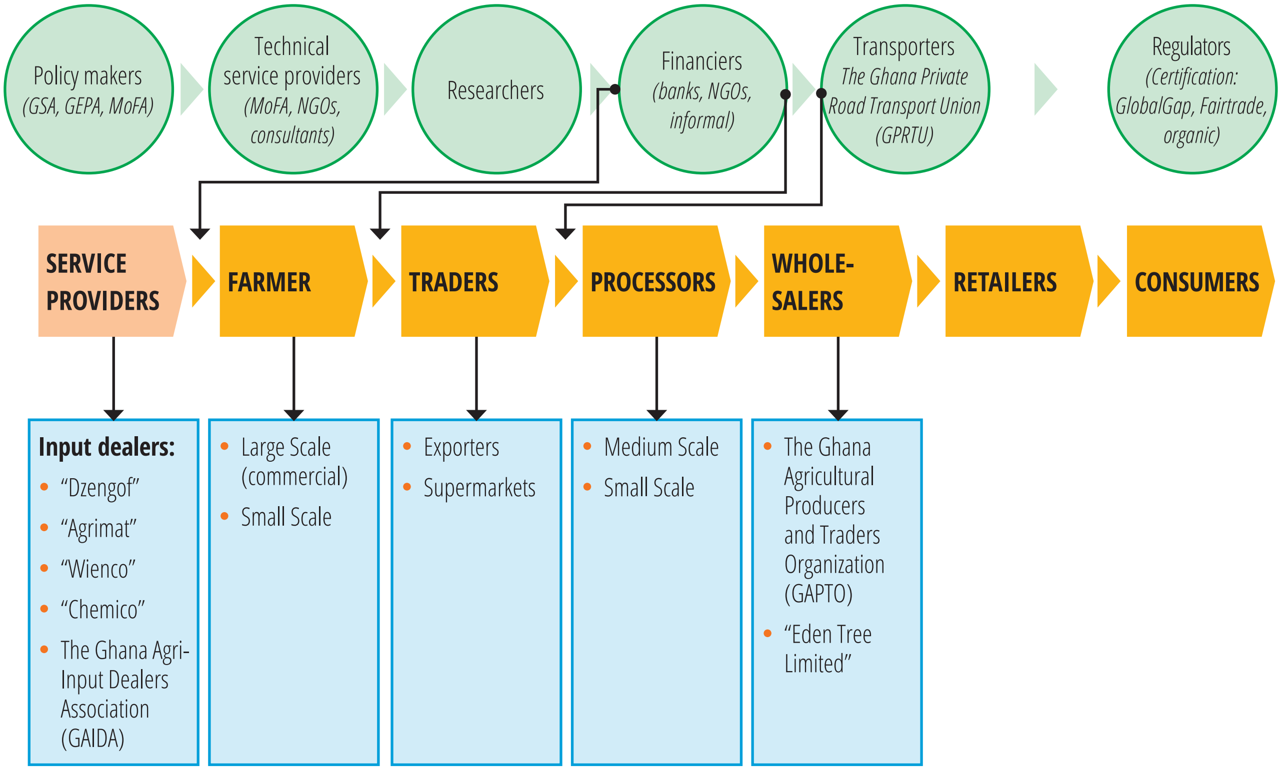


Figure 2. *Structural problems that affect the local vegetable industry*

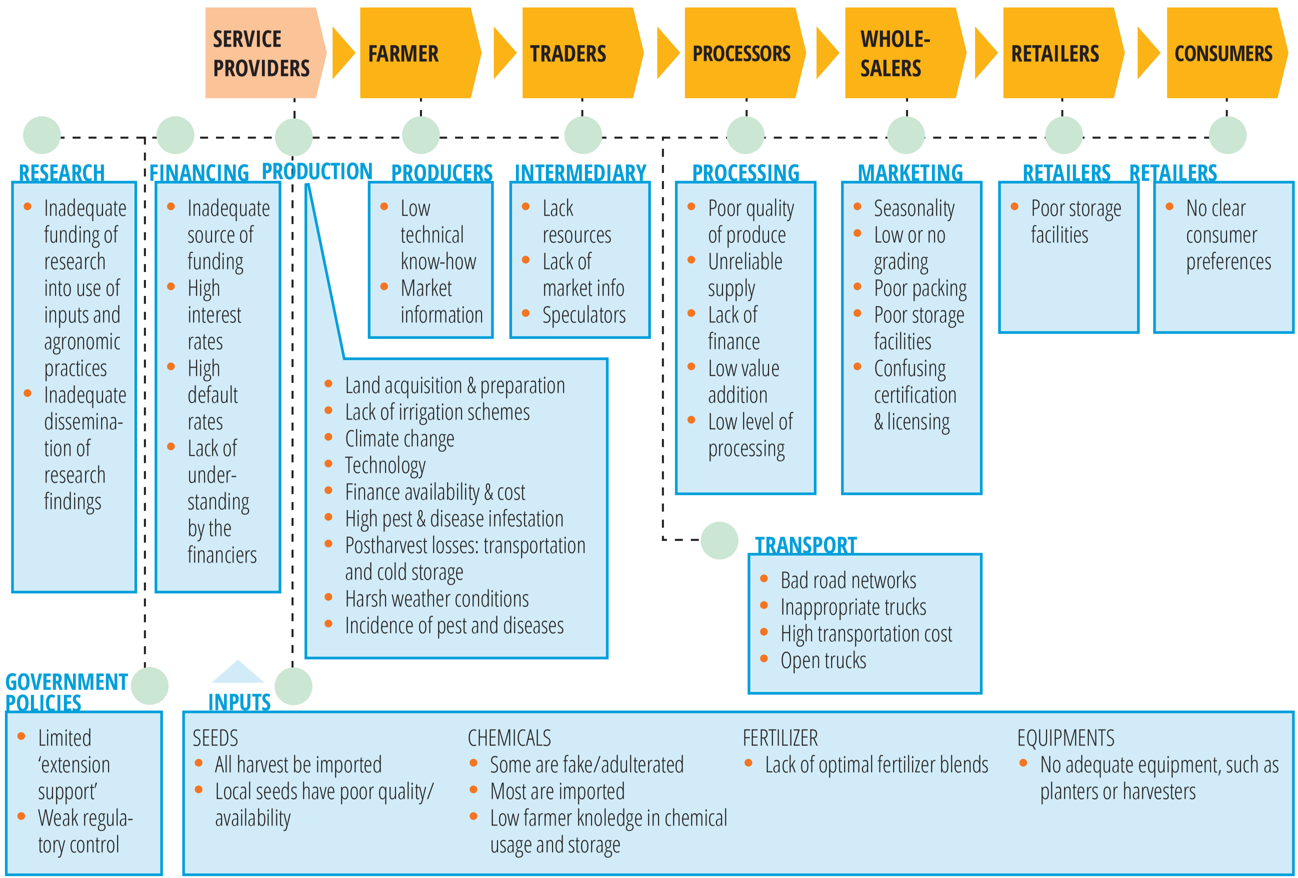
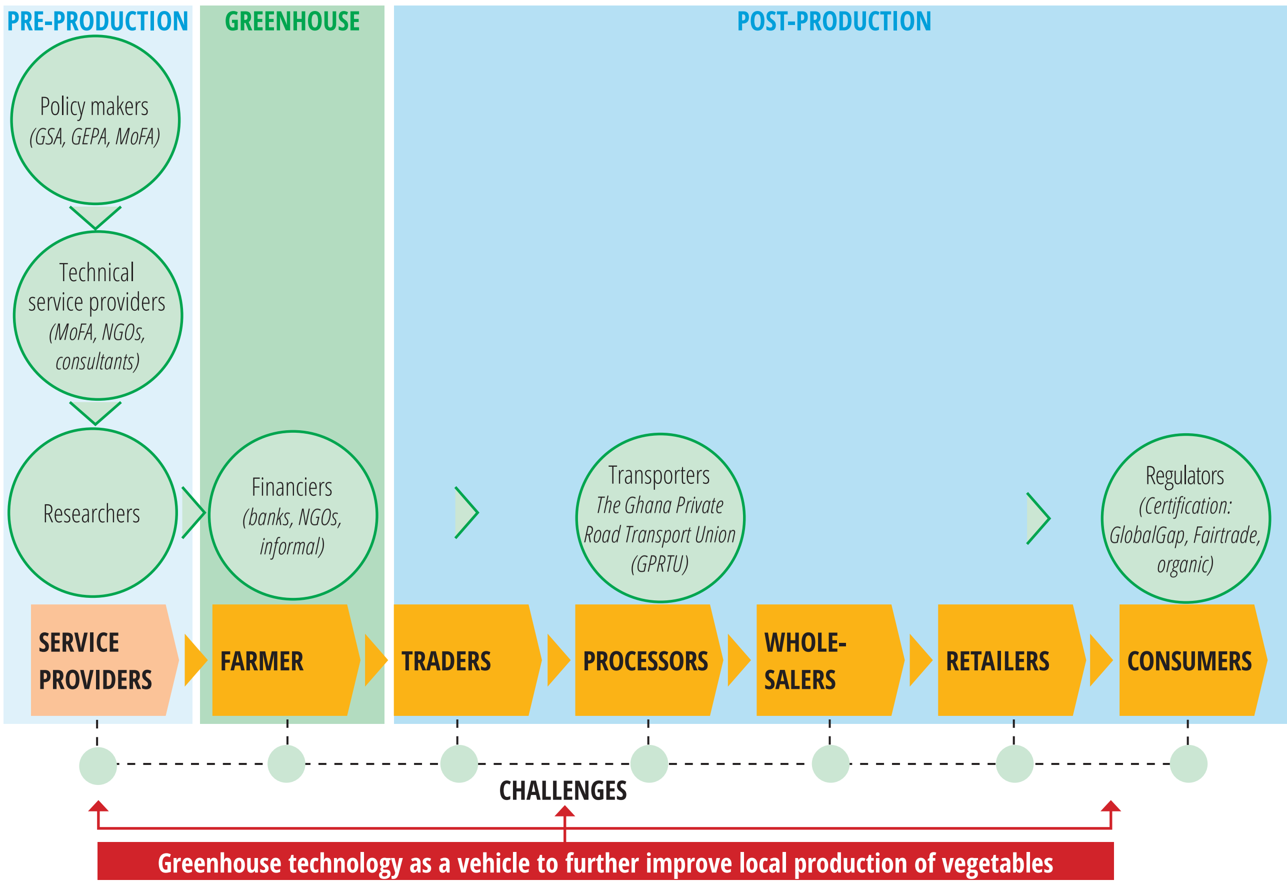


Figure 3. *Challenges related to the production of vegetables*



4.1 Pre-production aspects

4.1.1 Seeds and varieties

Both F1 hybrids and open-pollinated varieties (OPVs) are in use by Ghanaian growers – although greenhouse growers seem to use only hybrids. Seeds are supplied through for instance Dizengoff (East-West Seeds, PopVriend) and AgriMat (re-packing of bulk seeds in smaller quantities), but also other channels exist. In any case, growers must buy hybrid seed on the market. Self-multiplication of hybrids leads to segregation and ultimately OPVs. It may also be possible that much older OPVs that are not based on recent hybrids exist.

Seeds availability is not good in regions beyond the major cities. The major supply companies hold office in Accra, there may be some supply to cities such as Kumasi and Tamale, but more remote areas are not supplied. Good storage facilities are not available.

Most varieties in use are imported from foreign companies. Local breeding companies do not exist. Some breeding is done by for example the Kade Forest & Horticultural Crops Research Station, University of Ghana, the Savannah Agricultural Research Institute, as well as the Crops Research Institute in Kumasi, which produce some varieties that have received attention from growers (an example of a variety bred at FOHCREC, Kade is 'Nkansah HT' and at University of Ghana 'Legon 18'). The imported varieties include Mongal, Kirele, Roma VF, Momotaro, Nemo-neta, Platinum, Cindy Sweet, Season Red, Chibili, 4148, and Maya.

The suitability of available varieties to the growing conditions (climate, diseases) in Ghana remains unclear. A fairly large number of persons we spoke to claimed that the available imported varieties are not suitable to the Ghanaian climate and (strains of) diseases, and that locally bred varieties are suitable to local growing conditions. But on the other hand, we also observed crops that were doing relatively well if well managed. Our general impression is that crop failure is swiftly attributed to the genetic make-up of the crop, whereas improved greenhouse construction and crop management will just as well contribute to a better growing crop. Well-managed variety trials at different locations and under different management regimes in which a varieties from different origins are evaluated would be required to obtain reliable information. Breeding companies perform such trials with a limited selection of local varieties, however, a more structured approach is recommended. Such variety trials could include consumer preferences as one of the evaluation criteria and lead a diversified offer of tomatoes that meets market demands.

A strengthened breeding programme for Ghana would be very valuable. Commercial companies may take better into account the Ghanaian market, through for example selection and evaluation plots in Ghana, while the public sector may strengthening its breeding programmes through for example a more elaborate on-farm evaluation.

A seed law has been put in place, and a National Seed Council was established in April 2014. We did not check the details of the Ghanaian seed law.

The Ghanaian government favours local seed production. Technically, this seems most appropriate in the northern regions where relative air humidity is lower and crops can be cultivated better than elsewhere in the country in isolation. The current system for local seed production does not include vegetable seeds. Given the fact that the private breeding sector has available good hybrid varieties for vegetables, and has the capacity to make high-quality seeds available, it appears more effective to make use of the industry's strengths.

Some persons we spoke to, claimed that the price of seed is too high and is not affordable, whereas others acknowledged that good seed comes at a price.

Opportunities

Well-managed variety trials in good greenhouses, by researchers and growers.

Seed companies that provide F1 hybrid seeds that will give higher yields and resistance to bacterial wilt, fusarium wilt, other pest and diseases, as well as tolerance to high temperatures ridge gourd (Luffa acutangular).

The country-wide availability of a wider selection of varieties.

Collaboration between private breeding companies and the Ghanaian research sector in selection and evaluation of varieties, and in seed multiplication.

4.1.2 Crop protection agents

One of the main purposes of a greenhouse is to prevent pest insects from establishing on the crop, and to create a climate that is less conducive for the development of diseases (e.g., lower leaf wetness, removal of humid air). This appears not to be well understood by the majority of greenhouse growers in Ghana who permit holes in, or even complete rupture of the greenhouse cover; do not have a double-door sluice; and have a low understanding of crop hygiene in general. A serious investment in knowledge and awareness is needed.

The starting point is prevention, which implies a strict sanitation regime. For instance, growers should only enter the greenhouse if needed, wearing un-infected clothes, a disinfection mat should be at the entrance of the greenhouse, tools should be disinfected frequently, disease-infected plants must be removed and burned instantly, etc.

The general impression with regard to chemical protection means is that:

- Any product is available and used (!) in Ghana, legal or not legal. Even growers that claim to be organic use chemicals.
- Crop labelling is not always reliable.
- Spraying techniques and schemes are sub-standard.
- Resistance build-up in pest populations against active ingredients probably easily occurs.

This leads to high residue levels of pesticides in products, which is damaging for the consumer's health. Regularly, export shipments are rejected upon entry in Europe. MRL inspection in Ghana does not exist, and although there is an increasing demand for good-quality products in Ghana, it is difficult to see how this should lead to reduced use of chemicals in the present situation.

Along with better greenhouse construction and maintenance, better understanding and implementation of hygiene measures, biological crop protection would be a valuable contribution, as it would truly lead to reduced MRL levels. A local biological crop protection industry does not exist, implying that biological control agents would have to be imported from abroad. Soft chemicals would in this system (as is practiced in The Netherlands and many other countries) only be applied as a last resort.

Major pests and diseases:

a) tomato: late blight, white fly, damping off disease, and bacterial wilt.
b) sweet pepper are: white fly, black mold, and aphids.
c) okra: white fly and aphids.
d) cucurbits such as marrow, sweet melons and turia (or ridge gourd, *Luffa acutangular*): leaf miner, wilt and white fly.

Disease incidence increases during the humid rainy season, when it is hot and humid.

Opportunities

Integrated Pest Management, with reduced use of chemicals and greater use of biological control agents/bio-pesticides/organic pesticides (e.g., Pyrethrium).

An improved sanitary system.

Figure 4. *The Amiran type greenhouse (photo taken at NewEnergy in Tamale).*

Figure 5. *The Enviro Dome greenhouse (photo taken at Kade)*

Figure 6. *Greenhouses at Mr. Maroun's farm*

4.2 Greenhouse construction

4.2.1 Design

The limited differences in temperature and relative air humidity among locations do not lead to great difference in greenhouse design. Precise dimensions of ventilation openings may vary among locations, depending on winds speed, wind direction and temperature, however such a precise design would be location-specific. Neither do the various crops require different greenhouse designs. An exception can be made with respect to the opening of the top vent, that can be one-sided if the wind direction is stable, but should be two-sided if the wind direction is irregular (see paragraph 4.2.2).

The two major advantages to cultivate a crop in a greenhouse are the protection against adverse weather conditions such as hard winds and rains, and to protect the crop against pests (disease management requires other measures than a greenhouse construction). Winds and rains are usually dealt with (provided the construction is well maintained), but the greenhouse as a crop protection means requires much more attention. Important effects of the greenhouse cover on the climate are higher temperatures and levels of relative air humidity. High temperatures can be detrimental to the crop whereas high relative air humidity favours development of some diseases.

A number of basic greenhouse designs are:

1. Net house, soil cultivation, drip irrigation by gravity. This is the simplest and cheapest. The greenhouse requires a construction that supports the net, a water tank that is filled for instance once per day, and some tubes and valves to supply water to the plants. Even cheaper would be a greenhouse in which the plants are watered by hand. Disadvantages of a net house are permeability for rains, and the low light transmission and therefore reduced crop growth. Cultivation in the soil introduces the considerable risk of soil borne diseases.

   A simple net house would be suitable if investments funds are scarce but if growers want to make a first step in protected cultivation nevertheless.

2. Plastic house with fixed window openings (no electricity available). A plastic house offers better protection against rains and makes more light available to the crop. Yields are potentially higher. However, good ventilation is necessary.

   A plastic house with not-automated fertigation is suitable for regions where electricity is not (always) available. Because of the tank that must be filled periodically, amounts of water and therefore the acreage should be relatively small (e.g., 100–300 m²).

3. Plastic house with automated drip irrigation and mechanic ventilation, possibly with screens. Automated drip irrigation on the basis of radiation, temperature and/or soil moisture content requires electricity, and provides optimal amounts of water and nutrients to the crop. Mechanical ventilation ensures movement of the indoor air. Screens, provided they are retractable, can reduce light intensity when needed (e.g., cucumber, young plants, flowers if they would be cultivated). Flexible window openings are optional: they are useful if the need for ventilation varies. However, as ventilation requirements in Ghana are fairly high, windows are likely to be open all the time.

   A plastic house with automated fertigation is suitable for regions where electricity is guaranteed, where acreages are larger, and where sufficient technical knowledge is guaranteed.

The greenhouse types are expected to realize higher yield levels, although they also require higher levels of capital investment. Essential considerations in the decision are:

- Is electricity available?
- Can the greenhouse be maintained, are repairs possible at all times?
- Can the greenhouse staff deal with the amount of knowledge required to operate a more advanced greenhouse?
- Is the money to invest available?
- Does the pay-back time warrant the investments?

There are currently five greenhouse types present in Ghana.

Small greenhouses:

1. A greenhouse without top ventilation. An example of this is the old Amiran greenhouse type of which some 200 have been sold to growers. Side netting allows side ventilation. The top cover is made of plastic foil. This greenhouse is supplied by Dizengoff Ghana Ltd.

   The Amiran greenhouse measures 8 × 15 m (120 m²) and costs US$ 6,000, for which not only the greenhouse structure is supplied, but also the gravity-driven irrigation system, plus one season of inputs and support. Input costs are approximately US$ 300 per season.

2. A greenhouse with top ventilation through nets. An example of this is the new Amiran greenhouse type (which we did not see during our mission, but which were available, we were told by Dizengoff). At NewEnergy in Tamale the top cover of the old Amiran greenhouse was also made of nets.

3. A greenhouse with top ventilation through passive vents (round chimneys or windows). An example is the EnviroDome greenhouse at e.g. the Kade Forest and Horticultural Crops Research Institute, which is supplied by Stevicksen Ventures Ltd, manufactured by Eisenberg Agri (Bejing) Company. The EnviroDome greenhouses measures 11.3 × 24 = 271.2 m². Longer EnviroDome greenhouses measuring 60 × 11.3 m are available. The standard type is without fans but has side windows that are manually operated. A greenhouse with two compartments and ventilation fans can be supplied, or as a nursery house with platforms stands for raising seedlings, a cooling pad and fans. Aluminate shade netting can be installed inside or outside. The netting is double-sided, reflecting solar radiation during the day and reducing overexposure to heat, and reflecting IR radiation at night. The screen also reduces condensation on leaves and improves photosynthesis by increasing the amount of scattered light. The front door has dual-door system that reduces the number of insects entering. More advanced systems can be equipped with automatically controlled cooling, solar panels and full top ventilation.

4. Mr. Maroun Kadoun has realized at his farm greenhouses that he designed and constructed himself. Sides consist of nets, the top consists of plastic strips that are manually opened at the middle of the day.

Large greenhouses:

5. FreshFields at Juapong in the Volta region has established a number of larger, Israeli-constructed greenhouses that each measure 56 × 66 m = 3696 m².

6. Also Rovero has supplied a large greenhouse; however, this greenhouse was not visited during the mission.

4.2.2 Ventilation

As temperatures in Ghana are high, ventilation is very important. High temperatures have a negative effect on crop photosynthesis (even if stomata would remain open), pollination/fertilisation/fruit set, and the water balance. Only if the supply of water to the leaves remains adequate, stomata will remain open. However, at high temperatures and sub-optimal water supply this is very difficult to achieve, causing stomatal closure, reduction of crop growth and production, and high leaf temperatures that lead to damage to the leaves.

Therefore, ventilation is a must. This may be achieved through:

- Top ventilation opening.
- Sufficient side ventilation that allows the entrance of fresh air. A compromise has to be made between a small mesh size that blocks the entrance of insects, and a larger mesh size that allows good ventilation.
- A tilted side that realizes a greater ventilation surface.
- One-sided top ventilation if winds come predominantly from one direction.
- Two-sided top ventilation if winds come from various directions.
- A good transpiring crop that reduces air temperature. This is only possible if water supply is continuous and sufficient.

Local climate conditions determine the exact design. For example, the continuous winds from along the coast create a relatively good ventilation situation. The larger greenhouses at FreshField Farm, Juapong, were equipped with mechanical ventilators to ensure sufficient air circulation. The twin EnviroDome greenhouses at Kade also have mechanical ventilation which ensures good air circulation. These greenhouses are therefore an example of a slightly higher technology level. An example of a greenhouse with a 2-sided top opening has been realized earlier in a very different part of the world, e.g. in the tropical lowlands of Malaysia (see Figure 7).

Most greenhouse do not have automatic data loggers for measuring climatic parameters. Greenhouses at Kade have a thermohygrometer that record at certain times of the day (6.00 a.m., 9.00 a.m., 12.00 noon, 3.00 p.m. and 6.00 p.m.). Such climatic data or automatic equipment for measuring daily weather conditions is paramount in greenhouses.

Opportunities

A Ghana-specific greenhouse design that has sufficient natural ventilation capacity and is suitable for the local conditions.

A system with solar panels can supply energy for further cooling.

More detailed observation of climate data is needed. The use of data loggers, thermo hygrometers, light meters must be made available to growers to help measure climatic parameters.

Figure 7. *The greenhouse realized in Malaysia, suitable for a tropical climate. The greenhouse has a 2-sided top opening, tilted sides, nets along the sides that allow air entrance. With a mature, fully transpiring crop, an indoor temperature below the outdoor temperature is realized (Elings et al., 2012).*

4.2.3 Strength of the construction

The present greenhouses in Ghana are not always strong enough to withstand the high wind speeds that may occur. Various examples of broken plastic, or even collapsed greenhouses were observed with the Amiran Kits and FreshFields structures. A sufficiently strong construction is a first requirement, also if high wind speeds only rarely occur. Investments are high, insurance difficult, potential losses large, so security is required.

4.2.4 Crop protection

Most present greenhouses have a single door construction. This construction does not block insect entrance if the door is opened. A sluice construction with a double door is required. Only one door at a time should be opened. In addition, a floor mat with a disinfecting solution should be present at all times. The EnviroDome greenhouses have double door openings that reduce entry of insects.

In addition, greenhouse sides were not always well-closed with nets. Either repairs were (or could?) not carried out immediately, or the construction itself had open sides. Such observations were at Wenchi and FreshFields. A maintenance crew for repairs is very important to ensure worn out or damaged nets are quickly repaired.

4.3 Greenhouse installation

FERTIGATION

The simplest fertigation system, as supplied with the Amiran package, is gravity-based. A tank sufficiently large for the water needs of at least one day is placed on a construction a few meters high, and gravity ensures that the water is drip-irrigated to the plants. A purely manual system with a watering-can was not observed, and is neither recommended.

The EnviroDome and larger greenhouses have an electrical pump to drive the drip irrigation system to a water tank. Water is supplied to plants in the greenhouse by gravity through the loop irrigation system. Solar energy was used at Hikma Farms, and the EnviroDome greenhouses can be equipped with some solar panels at the top. Otherwise, electricity is obtained from the national grid.

Currently fertilizers for greenhouse fertigation are limited to only those supplied by Dizengoff. They supply 19-19-19 NPK soluble fertilizer and potassium-nitrate. Other fertilizers or straight fertilizers that can be mixed into tank A and B are needed including the micro-nutrients for proper growth of plants in greenhouses.

MECHANICAL VENTILATION

Small greenhouses (more specifically: narrow greenhouses) can do without mechanical ventilation, whereas larger (= wider) greenhouses require mechanical ventilation to avoid high air temperatures in the centre of the greenhouse. A pad and fan system was installed in one of the greenhouses at Kade Forest and Horticultural Crops Research Centre for the seedling house, while only fans were installed in some of the twin-greenhouses.

COMPUTERIZATION

Computerized systems that base fertigation on indoor or outdoor climate information, or on soil moisture content, are not in use in Ghana.

TECHNOLOGY LEVELS

Automated fertigation and mechanical ventilation are only possible if electricity is continuously available. If this is not the case, a gravity-based fertigation system is installed and greenhouse size is small to enable natural ventilation. The adoption of use of solar energy will help in the automated fertigation and mechanical ventilation, however, one must look at the costs of this.

Opportunity

Greenhouse companies to supply appropriate greenhouse materials for optimum production.

4.4 Soil and substrate

Part of the greenhouse growers grow in the soil, and part in pots that are filled with cocopeat, which is available from e.g. Dizengoff, or pots filled with soil. Other substrates available are perlite, carbonated rice husk, biochar and compost. Wenchi and Tamale use cocopeat while Kade and Volta grow in soil. Soil sterilization is done but this is not enough as bacterial wilt occurrence was observed in both soil and cocopeat substrate. More effective soil/substrate sterilization strategies must therefore be implemented (not necessarily chemical). Kade currently uses carbonated rice husk as substrate for the nursery and pot experiments, and plans to use substrates such as cocopeat, palm fibre, sawdust, rice husk and their combinations in the future.

The advantages of soil cultivation are the buffering capacities for especially water, but also nutrients, which is important in view of the regular power cuts. The major disadvantage is the presence of soil-borne diseases, such as bacterial wilt. Treatment of the soil with aggressive chemicals is potentially possible, but costly and knowledge-intensive.

The advantages of substrate cultivation in Ghana are the prevention of crop infection with soil-borne diseases, the potentially better possibilities to regulate nutrient availability to the crop (but this requires good regulation of the nutrients solution as well). The disadvantages are the shortage of especially water, but also nutrient supply to the crop in case of a power cut.

Interrupted power supply can be avoided by a back-up generator or by solar energy, whereas soil-borne diseases are difficult to avoid. In itself, soil can be treated with aggressive chemicals or long-term heating underneath plastic, however, this is cumbersome to realize in a greenhouse once it has been constructed. If soil is used in pots, the soil should be treated before the crop is planted.

Opportunity

Apply strategies for soil/substrate sterilization.

4.5 Inputs

Fertilizers that are normally used in open-field agriculture and horticulture appear to be widely available from the input suppliers; for example NPK 19-19-19 is used in greenhouses as well. Whereas the A/B system is customary in other countries, in Ghana water and chemical fertilizers are mixed in one tank from which the crop is drip irrigated. The EC and pH of the supply solution are sometimes checked, however, not by all growers. Measurement of soil characteristics rarely takes place. Growers would benefit from a laboratory that can quickly analyse soil samples, enabling them to better optimize their fertigation regime. Some growers (e.g., Mr. Maroun Kaddoun) enrich their soil with humus; otherwise, use of organic materials appears to be scarce.

Water for protected cultivation in Ghana is sourced from bore holes, rivers and dams, or the water net. However, irrigation constructions are relatively scarce in Ghana. In the Accra/Volta/Kade region, greenhouses are located nearby surface water sources or dams (apart from the growers that use water from a bore hole or the water net). In Kumasi, Wenchi, the one grower we visited used surface water from a nearby artificial lake. Surface water is scarce in the northern Tamale region, where water from bore holes or the public water supply has to be used.

Besides, it was often acknowledged that the surface water from rivers and dams is of doubtful quality, in terms of chemicals and human or animal excrements. In these cases, borehole water of water from the water net was used (borehole water in Accra may be saline due to the proximity of the seas). In cases where the risk of low-quality water was considered low, or not really considered at all, or where the costs of a borehole was considered too high, surface water was used.

The price of a bore hole depends on its depth. Prices mentioned varied between 8,000 GHS (€2,000) or a bore hole of 40–50 m at Hikma Farms) and 10,000 GHS (€2,500) by Dizengoff. On top of this, $4,000–5,000 (€3,000–3,700) for pump and solar panels should be added. At Hikma Farms, one greenhouse of 120 m^2 uses about 1 m^3 per day, which equals to 8.3 l m^{-2} day^{-1}. At a price of 0.25 GHS m^{-3}, this implies water costs of approximately 2 GHS m^{-2} d^{-1} (€ 0.5).

Energy: If gravity is used to supply water to the greenhouse, as is done in most simple greenhouses, no energy is required. However, if a pump is used for bringing water to the plants, continuous availability of electricity is required. The major source of electricity is the grid, which is unfortunately not fully reliable. Examples of senesced crops due to short and long-term interrupted water supply have been observed.

Energy is expensive: the commercial rate is 0.4 GHS KWh^{-1}, or more for large-scale application. An alternative is solar energy, which is a potentially reliable energy source in Ghana where solar radiation is high and often available. Excess solar energy can be supplied against commercial rates to the grid.

The EnviroDome supplied by Stevicksen Ventures Ltd (Eisenberg Agri (Bejing) Company) integrates a small row of solar panels at the top of the greenhouse, while NewEnergy/Hikma Farms uses 2nd hand solar panels that are placed besides the greenhouse to drive water pumps for drip irrigation. The 120 m^3 greenhouse needs 1 m^3 day^{-1}. This can be done with a system of 180 peakW. Systems come for 1.5 € W^{-1}, so costs are € 270.

Land: Some persons we met indicated that obtaining land is a problem, as land ownership is not with government but with chiefs with their own – rightful – priorities. In any case, land can not be really owned, but leased for 49 or 50 years (it used to be 90 years).

Other input supplies: Cultivation requires a wide range of other input supplies such as trays, ropes, tools, boots, spraying equipment, protective clothing, etc. Most of it is available through input suppliers; although it may take a trip to Accra to obtain more uncommon goods.

Opportunities

Wide implementation of solar energy.

Equipment dealers that supply data loggers, EC, pH meters, refractometers, soil kits, nutrient meters, etc. for data measurements in greenhouse.

Agro-input or fertilizer companies that supply fertilizers and other inputs.

A laboratory that can quickly analyse soil samples.

A good water infrastructure (borehole, simple irrigation facilities).

4.5.1 Human resources

The horticulture industry in Ghana has emerged as a vital sector for the economy of Ghana following the diversification of the country's export base. Ghana has seen some successes in various activities in the fresh fruits and vegetables value chain, especially in the pineapple sector. The cold chain is considered as one of the weak factors. Cultivation of vegetables under greenhouse conditions has commenced in Ghana on trial basis. Further development calls for human resource development and increased know-how in greenhouse production to support what the University of Ghana and some sectors have started in introducing greenhouse vegetable production.

The University of Ghana provides education in protected horticulture at the BSc, MSc and PhD level. Number of students are approximately 20, 5, and 2, respectively, while other universities may produce up to 50 at the BSc level. BSc students find employment with greenhouse growers as manager. While the level of education is adequate for immediate needs, many skills and much knowledge has to be gained in practice. Students with an MSc degree usually find employment in Agriculture institutions (Ministry of Food and Agriculture, Education and Research Institutes), and students with a PhD degree find employment in the Universities and Research Institutes.

Training for growers is also provided as part of Amiran kit, for one season. And other suppliers also provide knowledge with respect to the products they sell. This, however, can not replace the long-term and comprehensive approach that is needed.

Labourers are trained on-site by the greenhouse manager.

There is a need for improvement of education facilities, in terms of hardware, a more extensive curriculum than currently available, more experienced teachers, and hands-on practical training components.

Opportunities

A comprehensive training programme.

Training of more students and growers in greenhouse vegetable production.

4.6 Production

Vegetable production both in greenhouses and in the open field is affected by climate factors such as temperature, water availability, radiation, wind and relative air humidity. Most climate factors can be controlled to some extent in greenhouses, depending on the level of technology. The market demand also influences the decision which vegetable crop to grow at any particular period. Provided an assured market exists, it is better to restrict production to the crops that have a market rather than to grow a large range of vegetables.

In Ghana the most imperative and relevant crop is tomato, as this can fetch high prices in the market especially in the dry season (Agri Impact Consult, 2013). At the moment varieties in cultivation range in size, some of which are for salads, fresh market and processing.

Other crops that are of economic importance and that are considered high value vegetable crops include (green) pepper, cucumber, cabbage, carrots, okra, marrow, ridge gourd, squash, lettuce, spring onions, etc.

- Peppers grown in Ghana can be distinguished into four cultivar groups. These are Sweet pepper (paprika, bell pepper), Chilli (long hot types), Bird eye (Tabasco', Cayenne, Demon) and Aromatic pepper (Scotch Bonnet, Haberano). Bell pepper (green) is the most cultivated cultivar in Ghana as was seen at Hikma and FreshFields farms. Other cultivars with yellow and red colours have been evaluated at FOHCREC, Kade.
- Cucumber is produced at Marroun Farms and at FOHCREC, Kade. Both the determinate and indeterminate varieties are cultivated. FOHCREC evaluated 7 different cultivars. Most are parthenocarpic and do not need insects for pollination and fruit setting.
- Okra production in greenhouse was also carried out at FOHCREC, Kade with 5 different varieties. These included the Asian (*Abelmoschus esculentus* and the West African (*A. caillie*) cultivars. Cultivars evaluated included 'Clemson Spineless', 'Indiana', 'Volta', Najuka, Local, OH-152 and OH- 016.
- Other Asian vegetables, such as marrow (courgettes), tinda, turia (ridge gourd) were also evaluated and the challenge observed was the failure to set fruit as insects or bees were not present in the greenhouse (which calls for the introduction of bumble bees).
- Aubergines or eggplants such as Ravaya and the long purple cultivar are produced both for the local and export markets. Greenhouse production will have the advantage for export that infestation with thrips and other insect can be lower.
- Last but not the least leafy vegetables and brassica crops like cabbage and cauliflower production could be encouraged in greenhouse to prevent insects and pests attack. These crops can be cultivated in the dry season in places where they do not produce tomatoes in greenhouse.
- High value crops such as sweet melon should be encouraged in the dry season as they have premium prices for the super markets and hotels, and opportunities for exports. Production is done in the Volta region and in Sogakope in the coastal savannah. FreshFields can produce melons in the dry season if hand pollination can be effected. Production in the north will be best for sweet melons because of the dry weather conditions.

Vegetable production can be for the fresh market, seed processing or food processing. However, production for the fresh market is most widespread the others require more specialized techniques. Depending on the type of enterprise its varieties must be acceptable to the consumer.

Provided sufficient water is supplied, it appears that all crops can be grown in all visited regions of Ghana, as the climatic differences are limited. The quality of crop protection and general production skills are more important determining factors.

Tamale is to some extent an exception, as greenhouse crops can be grown here in isolation from other crops, which offers opportunities for e.g. breeding companies.

4.6.1 Tomato

Production in the greenhouse should be approximately 20 kg m^{-2} over a 5-month period (please note that not all months are productive). With two growing seasons per year, this results in an annual production of approximately 40 kg m^{-2} per year. But production levels can also be lower: reported production levels per season at Kade were 16.15 kg m^{-2}, 6.9 kg m^{-2} in Wenchi, and 8.4 kg m^{-2} in Tamale.

Also note that outdoor production levels are much lower (Robinson & Kolavalli, 2010): two thirds of the farmers have yields of less than 10 tons ha^{-1} (which is 1 kg m^{-2}; not clear whether this is on a seasonal or yearly basis). This in itself illustrates the impact that a greenhouse cultivation system has on crop productivity.

Plant density at Kade range from 3.5 to 5.5 plants m^{-2} (952 to 1500 plants per 271.2 m^{-2}). Plant density at Wenchi and Tamale are lower at 2.5 5 plants m^{-2} (300 plants per 120m^{-2}), while plant density in Volta (Yave) is even lower at 2.16 plants m^{-2} (8000 plants per 3696 m^2 greenhouse).

Usually, only one stem per plant is maintained.

Opportunities

Yields can be largely improved through better management practices.

An advisory role by experienced growers with regards to good agricultural management practices.

4.7 Post-harvest

Post-harvest management practices include cleaning, sorting and packing, storage (cooling) and transportation.

Stakeholders interviewed indicated that overall no cleaning practices are carried out. Only some companies sort and pack the fresh produce. None of the interviewed companies reported having cold storage in their facilities. The fresh produce is therefore harvested and delivered the same day or the next day at the latest. Interestingly, all companies had no clear recollection of the post-harvest losses accrued throughout the year. In this regard, book keeping seems to be an opportunity.

It is not a surprise that logistics have a direct impact on the distribution, marketing and ultimately on the prices fetched by farmers. As experienced during the field visits, the road infrastructure becomes precarious as one drives off the main road and onto feeder roads. Generally speaking, the roads that connect farms with local markets are characterized by gullies and ditches, and even in some parts one might expect that roads are difficult to access by motorized transport during the rainy season. With respect to the means of transportation used, farmers are familiar with 5–6 ton open trucks. The majority of these vehicles carries the produce from the farm to the market in precarious conditions, with no cooling system and, on some occasions, no cover to confine the load. The distance travelled is another factor that needs to be considered.

Interviewed companies dealing with greenhouse produce indicated that they operate standard trucks with no other special consideration. On the other hand, the distance travelled was, in most cases, not greater than 20 km. As far as transport is concerned, companies prefer a production locations that is relatively close to potential buyers (see chapter 6.1.3.) In this way post-harvest losses and cost of transportation (fuel plus driver) can be kept at reasonable levels.

There exist five processing plants for tomato paste and ketchup in Ghana which are not functional due to the lack of volume and right varieties produced. Consequently, around 70,000–80,000 tons per year of tomato paste is imported from neighbouring countries to meet the local demand. One interviewee suggested that greenhouse technology can provide the volume needed and fetch a competitive price as opposed to those of imported tomato paste and fresh market. This testimony does not necessarily represent the consultants' view, which remain sceptical based on the high prices that producers can earn in specialized markets, and based on the low price of imported tomato paste.

Opportunities

Cold stores to reduce post-harvest losses and decline of quality.

Improved book keeping.

Introduce cleaning, sorting and packing practices to reduce product loss and increase value of produce.

4.8 The national market for greenhouse produce

Ghana is taking the first steps toward creating a reliable and competitive protected cultivation industry. As a key element to the success of Greenhouse technology, we looked at the potential national demand for greenhouse produce and the marketing channels already existing.

Farmers market their produce through different channels (Figure 9):

A) Farmer grows, harvests, transports and sells the produce at the local market. Transportation is arranged with other farmers so costs are bearable.

B) Farmer grows, harvests, transports and sells the produce to the local vendors (mostly women ('market queens')) located in the local markets.

C) Farmer grows, harvests, transports and sells the produce in the so-called corner shops. This system is used by farmers who produce above average quality vegetables.

D) Farmers grows, harvests and sells the produce to aggregators, who then decide where to sell the produce.

E) Farmers grows, harvests, transports and sells the produce in markets for expats. This channel is utilized by farmers with above-average skills and means of finance or investment.

F) Farmer has a contractual agreement with local supermarket chains, airlines, restaurants or hotels to sell his produce on a regular basis.

A, B, C, and to a lesser extend D, are ultimately ruled by the market queens, who set the market price for the various commodities grown in open fields throughout the year.

Companies noted that buying agreements were reached with restaurants, hotels and airlines. The buying requirements are: agreed volume all year round, appropriate sizes and overall health and quality of the batch. Through this buying agreement farmers can by-pass the market queens easily.

In return, companies fetch higher prices than those of open field produce (see 4.9).

Opportunity

Establish direct linkages between potential buyers and producers, and inform farmers of demand for products cultivated in protected environment.

Figure 8. *Marketing channels for local produce (to serve local demand)*

	NATIONAL MARKET			
A)	Production	Harvest	Transport	Sales at Fresh market
B)	Production	Harvest	Transport	Sales to local vendors (market queens)
C)	Production	Harvest	Transport	Sales at corner shops
D)	Production	Harvest	Sales to aggregators	
E)	Production	Harvest	Transport	Sales at Expat markets
F)	Production	Harvest	Transport	Sales to supermarket chains, airlines, restaurants and hotels

Marketing channel for greenhouse produce in Ghana at the moment

4.9 Costs and benefits

4.9.1 Tomato

Four different situations (Table 2; more details are provided in Annex 5) were evaluated for costs and benefits, varying in tomato price, presence of solar panel + pump, and financing term. The tomato price varies between 2.5 and 4.5 GHS kg^{-1} (0.625 – 1.125 € kg^{-1}) depending on the season and quality (outdoor tomatoes fetch 1.5 GHS kg^{-1}; and imported tomatoes fetch a retail price of 40–50 GHS kg^{-1} or 1 – 1.25 € kg^{-1}) mostly during the dry season). A solar panel + pump is required if water and electricity are absent. If electricity is present, a pump would be sufficient. The general assumptions for all scenarios studied are summarized in Table 3. We have restricted ourselves to a small greenhouse of the Amiran type. Other greenhouses with other sizes will result in different costs and benefits, however, comparative differences will remain the same. We have assumed no subsidies and no costs for electricity (as solar panels are used) and no costs for water. Also, income of the greenhouse owner is not accounted for – this will need to be deducted from the cash flow.

Producers fetch higher prices when supplying to more specialized markets. The higher price is explained by the low supply of quality tomatoes and other vegetables during the dry season. The bulk market is served by approximately 100,000 tons of tomatoes of doubtful quality from Burkina Faso are imported from December through May every year. Aside from other factors, this figure shows the potential market for companies that produce tomatoes and other vegetables all year round.

Tomato production is the most popular crop produced in a controlled environment in Ghana. The cost–benefit analysis is based on data obtained from a limited number of companies and should therefore only be considered as an entry point for information-sharing on greenhouse technology in Ghana. A more detailed economic analysis is recommended.

The results of the scenario studies are summarized in Table 4. More detailed results can be found Annex 5.

Table 2. *Scenarios evaluated in cost-benefit analysis*

Scenario	Tomato price (GHS kg^{-1})	Tomato price (€ kg^{-1})	Solar panel + pump	Financing term (years)
1	2.5	0.625	No	3
2	4.5	1.125	No	3
3	2.5	0.625	Yes	5
4	4.5	1.125	Yes	4

Table 3. *General assumptions for scenarios studied*

General assumptions:	
Greenhouse area (m²)	120
Yield (kg m^{-2})	40
Investment costs greenhouse ($)	6000
Subsidies (€)	0
Material costs (€ y^{-1})	300
Labour costs (€ y^{-1})	450
Electricity costs (solar panel!)	0
Water costs	0
Inflation (%)	15
Annual salary increase (%)	15
Interest (%)	28
Maintenance (%)	4
Depreciation (%)	15
Financing term (years)	3
Exchange rate € to US$	1.35
Exchange rate € to GHS	4

Table 4. *Results of the scenario studies (amounts are in (€ y^{-1}).*

SCENARIO 1

Tomato price: 2.5 GHS kg^{-1} (0.625 € kg^{-1})

Solar panel + pumps: no

Financing term: 3 years

year	1	2	3	4	5	6
Cash flow after capital payment and interest	3,617−	135−	637	1,463	3,624	4,168
Cumulative cash flow after capital payment and interest	3,617−	3,752−	3,115−	1,653−	1,972	6,140
Cumulative profits	3,000	6,450	10,418	14,980	20,227	26,261
Cumulative costs (including depreciation)	2,839	5,817	8,540	11,033	13,322	15,855
Cumulative net profit	161	633	1,877	3,947	6,905	10,406

SCENARIO 2

Tomato price: 4.5 GHS kg^{-1} (1.125 € kg^{-1})

Solar panel + pumps: no

Financing term: 3 years

year	1	2	3	4	5	6
Cash flow after capital payment and interest	1,217−	2,625	3,811	5,113	7,822	8,995
Cumulative cash flow after capital payment and interest	1,217−	1,408	5,219	10,331	18,153	27,149
Cumulative profits	5,400	11,610	18,752	26,964	36,409	47,270
Cumulative costs (including depreciation)	2,839	5,817	8,540	11,033	13,322	15,855
Cumulative net profit	2,561	5,793	10,211	15,931	23,087	31,415

SCENARIO 3

Tomato price: 2.5 GHS kg^{-1} (0.625 € kg^{-1})

Solar panel + pumps: yes

Financing term: 5 years

year	1	2	3	4	5	6
Cash flow after capital payment and interest	5,083−	179−	482	1,195	1,969	2,812
Cumulative cash flow after capital payment and interest	5,083−	5,263−	4,781−	3,586−	1,617−	1,195
Cumulative profits	3,000	6,450	10,418	14,980	20,227	26,261
Cumulative costs (including depreciation)	3,361	6,868	10,232	13,477	16,633	19,733
Cumulative net profit	361−	418−	186	1,503	3,594	6,528

SCENARIO 4

Tomato price:
4.5 GHS kg^{-1}
(1.125 € kg^{-1})

Solar panel + pumps:
yes

Financing term:
4 years

year	1	2	3	4	5	6
Cash flow after capital payment and interest	2,683–	2,342	3,495	4,762	6,161	8,906
Cumulative cash flow after capital payment and interest	2,683–	341–	3,153	7,915	14,076	22,982
Cumulative profits	5,400	11,610	18,752	26,964	36,409	47,270
Cumulative costs (including depreciation)	3,361	6,868	10,154	13,244	16,166	18,955
Cumulative net profit	2,039	4,742	8,598	13,721	20,243	28,315

The tomato price (2.5 or 4.5 GHS kg^{-1}) has a large effect on cash flow and cumulative net profit, just as investments in solar panels + pumps have. The effect of 2.5 or 4.5 GHS kg^{-1} is illustrated in the first two examples. A tomato price of 2.5 GHS kg^{-1} results in a positive cumulative cash flow in year 5, while a tomato price of 4.5 GHS kg^{-1} results in a positive cumulative cash flow in year 2. Cash flow in the first year is always negative because of the investments made in that year, but are positive from the 2nd or 3rd year onwards. A serious problem in Ghana is the high interest rate of 28%, which obviously has a negative effect on the cash flow. Alternative financing schemes that realize a lower interest rate will have a positive effect on the cash flow. Depreciation (15%) is included in the cumulative costs. The difference between cumulative profits and costs is the cumulative net profits. These are positive in most cases, except in the example in which a low tomato price of 4.5 GHS kg^{-1} is combined with investments in solar panels and a pump. Different scenarios will of course result in other values, but the general patterns will be similar.

Note that the prices given by producers are significantly lower than that of imported tomatoes from Burkina Faso or South Africa, which is set at around 30–50 GHS kg^{-1} (7.5–12.5 € kg^{-1}). It is worth mentioning that the farm gate price for greenhouse tomato, according to Dizengoff, is 5 GHS kg^{-1} (1.25 € kg^{-1}).

Potential investors need a consistent basis for assessing the economic viability of greenhouses in Ghana. In the above paragraphs and Annex 5 we provide a cost and benefit analysis of greenhouses dedicated to tomato production. By quantifying all significant costs and benefits in monetary terms we conclude that when the farm price is 4.5 GHS kg^{-1} (1.125 € kg^{-1}) and yields about 40 kg m^{-2} then investment will start yielding benefits after the third year (solar panel and pumps factored in, when not then potential gains occur from the second year). By contrast, when prices are close to those of open markets (2.5GHS kg^{-1}; 0.625 € kg^{-1}) then potential investments become less financially attractive.

If greenhouse costs are reduced (we now assumed an Amiran-type greenhouse), which is quite well possible if local construction is realized, or if competing suppliers enter the market, then greenhouse production could be even more beneficial.

Opportunity

Determine for other greenhouses (construction + installation) the cost-benefit analysis to make opportunities for commercial investments more transparent.

4.9.2 Sweet pepper

During the rainy season the prices for open field sweet peppers (1.5–2 GHS kg^{-1} (0.375–0.5 € kg^{-1})) and those grown in greenhouses (2.5 GHS kg^{-1} (0.625 € kg^{-1})) are comparable. A staggering difference in price is found during the dry season, however. Retail prices consulted in large supermarket chains vary between 30 and 50 GHS per kg. (7.5–12.5 € kg^{-1}). Nevertheless, it is believed that only small amounts at this price are sold weekly. At this time, sweet peppers consumed in Ghana come mostly from neighbouring countries. This figure hints at the potential that greenhouse production could have during the dry season. With respect to productivity, greenhouse yields were claimed to vary between 8 and 12 kg m^{-2} as compared to the 6 kg m^{-2} in the open field (we present these production data with some caution).

All in all, cultivation during the dry season offers a greater market opportunity for greenhouse technology than that of the rainy season since prices are comparable.

4.9.3 Financial services

In case of obtaining a bank loan, interest rates are very high (26–28%). Furthermore, the banks strictly check on the company's cash flow statement, which makes it difficult for individual (young) farmers to get access to loans. Many of the building materials are imported on a tax and VAT free regime. Stakeholders made explicit that although no taxes are in place, the price of acquiring materials from abroad exceed in many cases their purchasing power. This coupled with poor access to financial services hamper the development of the greenhouse sector. In order to reduce costs of equipment and material, growers could alternatively turn to the local industry and source basic equipment and materials. Unfortunately, almost no local materials were observed in the various systems visited.

Opportunity

A local industry of greenhouse equipment and materials as currently everything is imported.

It is noted that an improved production system may lead to higher production levels and product quality. This obviously has consequences for the cost-benefit analysis, the value chain and markets, and business opportunities. Such effects will be considered. ■

5. Opportunities

The opportunities mentioned in the previous paragraphs can be grouped in two ways, i.e. opportunities for the greenhouse sector versus opportunities for the broader horticultural and agricultural sector, and business versus general opportunities (Table 5).

Business opportunities for the greenhouse sector are:

a) Greenhouses adapted to the local climate, greenhouse equipment, solar energy, sensors and data loggers. A local industry fabricating and maintaining goods.

b) Variety trials, F1 hybrid seed.

c) Integrated pest management, biological control. ■

Table 5. *Summary of opportunities*

Greenhouse	Horticulture & agriculture
Business • Greenhouses with good climate management that enable indoor production during (part of) the dry season when prices are high. This must be accompanied by irrigation water supply. A Ghana-specific greenhouse design that has sufficient natural ventilation capacity and is suitable for the local conditions. • A local industry of greenhouse equipment and materials as currently everything is imported. • Wide implementation of solar energy, e.g. solar panels to supply energy for cooling. • Data loggers, thermo hygrometers, light meters that help growers to measure climate parameters. • Well-managed variety trials in good greenhouses, by researchers and growers. • Hybrid varieties that give higher yields and resistance to bacterial wilt, fusarium wilt, other pest and diseases, as well as tolerance to high temperatures. • Integrated Pest Management, with reduced use of chemicals and greater use of biological control agents/bio-pesticides/organic pesticides (e.g. Pyrethrium).	**Business** • The country-wide availability of a wider selection of varieties. • Agro-input or fertilizer companies that supply fertilizers and other inputs. • A laboratory that can quickly analyse soil samples. • Cold stores to reduce post-harvest losses and decline of quality. • Introduce cleaning, sorting and packing practices to reduce product loss and increase value of produce.
General • An improved sanitary system in greenhouses. • Strategies for soil/substrate sterilization. • Establishment of direct linkages between potential buyers and producers, and inform farmers of demand for protected cultivation. • Determine for more greenhouses (construction + installation) the cost-benefit analysis to make opportunities for commercial investments more transparent.	**General** • A good water infrastructure (borehole, simple irrigation facilities). • Collaboration between private breeding companies and the Ghanaian research sector in selection and evaluation of varieties, and in seed multiplication. • A comprehensive training programme. Training of more students and growers in greenhouse vegetable production. • Yields can be largely improved through better management practices. • An advisory role by experienced growers with regards to good agricultural management practices. • Improved book keeping.

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Annex 1. Mission details

Itinerary

The mission took place from Sunday May 18th to Saturday May 25th.

Three agroecological regions were visited, viz.

- Accra & Kade + Volta region (location Juapong)
- Kumasi region (location Wenchi)
- Tamale region

The following stakeholders were visited or spoken with during the mission (including the stakeholder workshop):

Suppliers	Dizengoff Ghana Ltd AgriGhana Ltd NewEnergy Stevicksen Ventures Ltd (Eisenberg Agri (Bejing) Company; EAC)
Producers	FreshField African Boreholes Initiative NewEnergy/Hikma Farms Maroun Kadoun's Farm
Exporters	Various exporters attended the workshop
Research	Forest and Horticultural Crops Research Centre, Kade Savannah Agricultural Research Institute
Government	Ministry of Food & Agriculture, Directorate of Crop Services
Greenhouses seen at	FreshField, Yave, Volta Region (Figure 9) Forest and Horticultural Crops Research Centre, Kade (Figure 10) African Boreholes Initiative, Wenchi (Figure 11) NewEnergy/Hikma Farms, Tamale (Figure 12) Maroun Kaddoun's Farm, Akuse (see on page 7)

Figure 9. *FreshField, Yave, Volta region.*

Figure 10. *The Forest and Horticultural Crops Research Centre, Kade*

Figure 11. *The African Boreholes Initiative, Wenchi*

Figure 12. *NewEnergy/Hikma Farms, Tamale.*

Date	Activity	Location	Team
Sunday May 18	KL 589 Amsterdam–Accra		Elings, Saavedra
	Kade–Accra		Nkansah
	Stay overnight	Accra	All
Monday May 19	Finalization programme at GhanaVeg/IFDC • Enam Gbekor • Hanson Arthur	Accra	All
	Dizengoff Ghana Ltd. • Samuel Abbey, Country Integrated Projects Manager	Accra	All
	Car drive Accra–Juapong		
	FreshField	Juapong	All
	Car drive Juapong–Accra		
	Stay overnight	Accra	All
Tuesday May 20	AgriGhana Ltd. • Aviram Tal, Managing Director	Accra	All
	Car drive Accra–Kade		
	Forest and Horticultural Crops Research Centre, Kade • Prof. G.O. Nkansah	Kade	All
	Car drive Kade–Accra		
	Ministry of Food & Agriculture, Directorate of Crop Services • Emmanuel Asante-Krobea, Director	Accra	All
	Stay overnight	Accra	All

Date	Activity	Location	Team
Wednesday May 21	AW 102 Accra–Kumasi Car drive Kumasi–Wenchi		All
	ACSL/African Boreholes Initiative, Ltd. • Ben Ore Ben Isreal	Wenchi	All
	Car drive Wenchi–Techiman		
	Stay overnight	Techiman	All
Thursday May 22	Car drive Techiman–Tamale		
	AW 161 Tamale–Accra		Saavedra
	NewEnergy/Hikma Farm	Tamale	Elings, Nkansah
	Savannah Agricultural Research Institute • Dr. Nicholas N. Denwar, Research Scientist Breeding & Genetics • Robert Kwasi Owusu, Postharvest & Food Preservation Engineer • Dr. Benjamin D.K. Ahaibor, Soil Microbiology-Fertility	Tamale	Elings, Nkansah
	Report writing		
Friday May 23	AW 161 Tamale–Accra		Elings, Nkansah
	Stakeholder workshop	Accra	All
Saturday May 24	Stevickse Ventures Ltd • Abdubakar Abdullahi, General Manager • Steve Akorli, Chief Executive Officer • Mawuli Agbeko Lumor, Agriculturist	Accra	Elings, Nkansah
	Maroun Kaddoun's Farm	Accra	Elings, Nkansah
	Greenhouse construction site (Environdrome)	Accra	Elings, Nkansah
Sunday May 25	Report writing		
Monday May 26	Accra–Kade		Nkansah
Tuesday May 27	KL 590 Accra–Amsterdam		Saavedra
Wednesday May 28	KL 590 Accra–Amsterdam		Elings

Annex 2. Workshop Programme

GhanaVeg Stakeholder Workshop

Exploring Emerging Opportunities in Protected (Greenhouse) Cultivation for Ghana's Vegetable Sector

Friday May 23, 2014, La Villa Boutique Hotel, Osu, Accra

Program Outline

Time	Agenda	Facilitator
11h00 – 11h15	Coffee & Tea – Cuppa Tea Session	Participants
11h15 – 11h25	Welcome and Introduction	Dr Anne Elings & Participants
11h25 – 11h35	Purpose of Workshop	Dr Anne Elings
11h35 – 11h45	Approach of Workshop	Yeray Saavedra Gonzalez
11h45 – 13h00	Break Away Group Session – *Identifying Business Opportunities*	Yeray Saavedra Gonzalez
13h00 – 14h00	Lunch Break	Participants
14h00 – 15h00	Plenary Session – Group Reports and Q&A	Group Leaders
14h00 – 14h45	Plenary Discussion – Proposed Priorities for the GhanaVeg Program	Prof George Nkansah
14h45 – 15h00	Closing Remarks	Dr Anne Elings
15h00 – 16h00	Interactions and Departure	Participants

Annex 3. The adaptive greenhouse approach

Greenhouse design depends on various parameters that characterize the construction and management options for temperature, radiation, CO_2 and humidity. These climate characters determine with water and nutrient availability the cultivation options and production level. The goal is to design a greenhouse that is economically feasible for a specific crop and given location. At the same time criteria such as water use efficiency, energy saving, and food safety can be considered. If the complete version of the adaptive greenhouse approach is followed then greenhouse designs are evaluated and compared in terms of crop production, economics and resource use (efficiency) by varying installation parameters like heating, cooling, screening, covering etc. Depending on the market prices year-round production is considered. For every design the resources (energy, water, nutrients, labour, carbon dioxide) needed are calculated. The design also determines the level of food safety (reduced pesticide use) that can be achieved. The quality of labour is related to the level of technology applied in the greenhouse design. This elaborate approach involves the use of three computational models, viz. the KASPRO greenhouse model, the INTKAM crop growth model, and a financial model. This complete version of the "adaptive greenhouse" approach consists of the following steps:

a) Identification of data sources: climate, production, water use, energy, prices, etc.

b) Definition of objectives: e.g., minimal water use, minimal energy use, high production, and high product quality.

c) Definition of required functions: e.g., crops, cultivation systems, labour, energy use, heating, cooling, reduction of energy loss, etc.

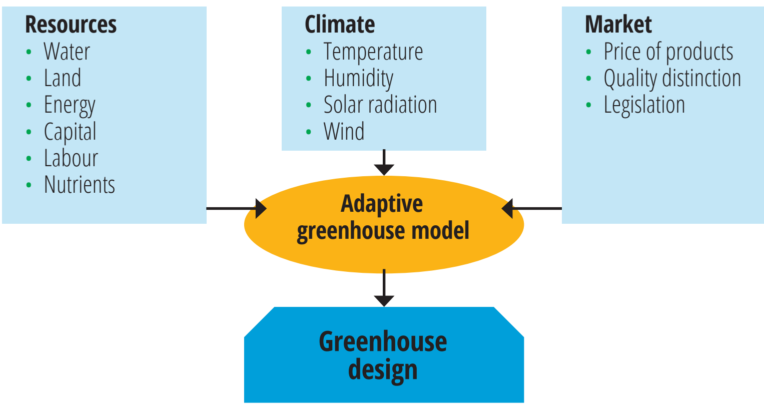
d) Description of various economical greenhouse designs.

e) Description of transition paths. These transition paths not only include the greenhouse itself, but also knowledge, institutional infrastructure, post-harvest issues, etc.

f) Workshop with stakeholders to increase awareness with the government and private sector, and define market opportunities.

g) Briefing of entrepreneurs in Ghana and The Netherlands, indicating market opportunities.

Figure 13. *Schematic overview of the adaptive greenhouse approach*

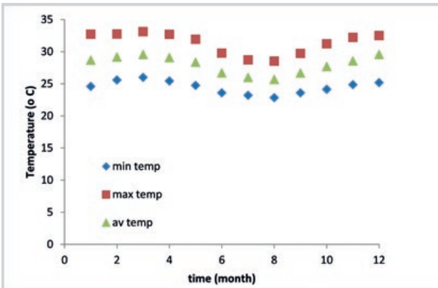


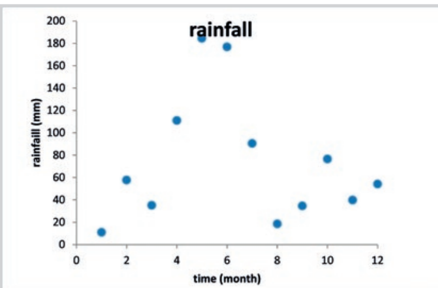
Annex 4. Climate information

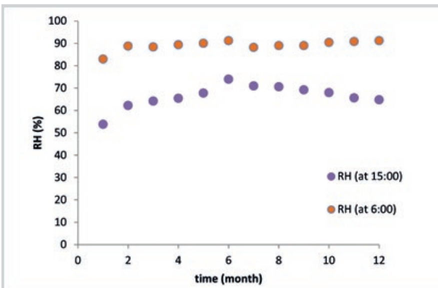
Figure 14. *Locations for which climate information is presented*

Figure 15. *Long-term climate characters for Accra and Kpando (Volta)*

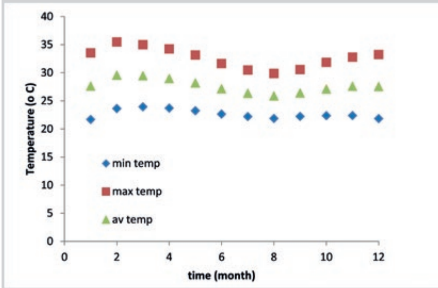
Accra

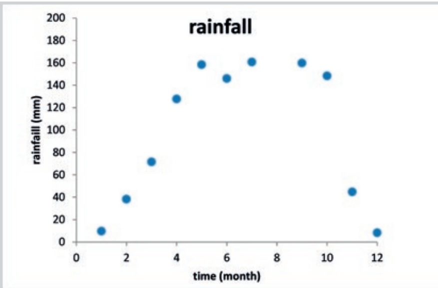






Kpando (Volta)





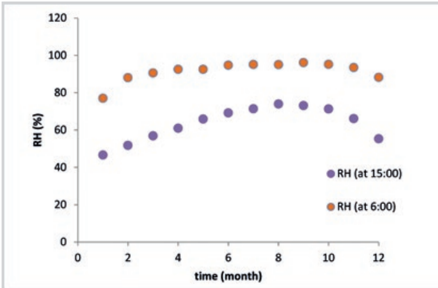
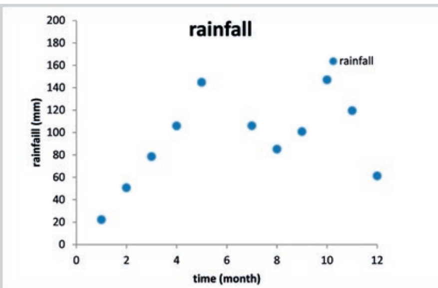


Figure 16. *Long-term rainfall patters for Nsawam and Aburi, both near Accra*

Nsawam



Aburi

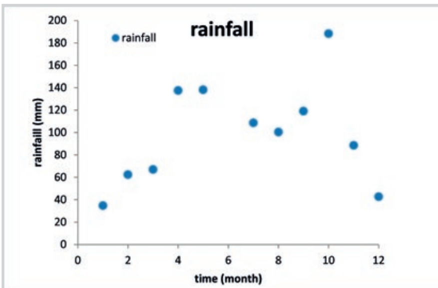
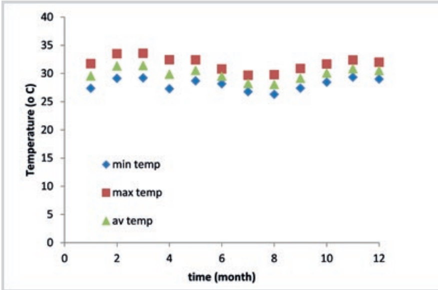
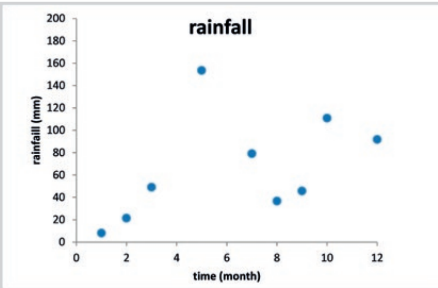
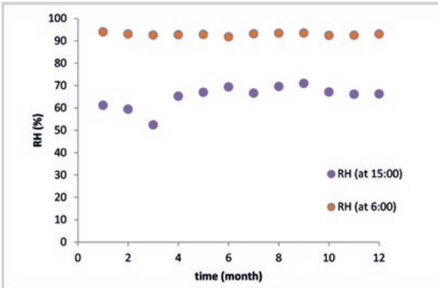


Figure 17. *Long-term climate characters for Kade and Kumasi*

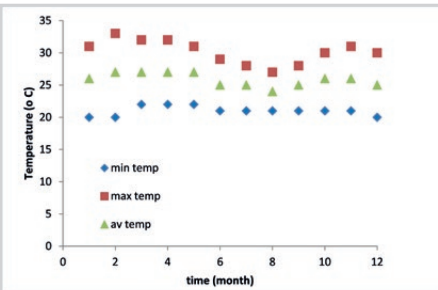
Kade







Kumasi



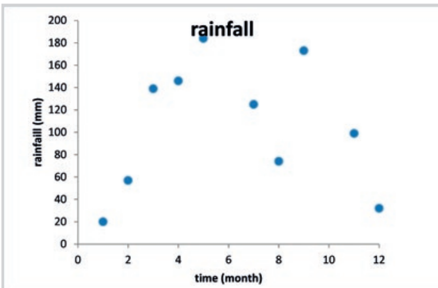
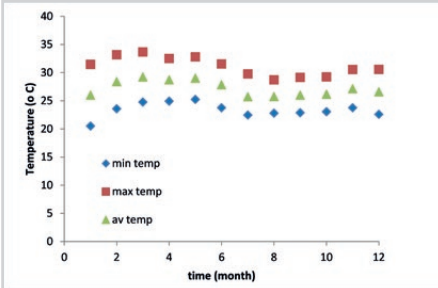
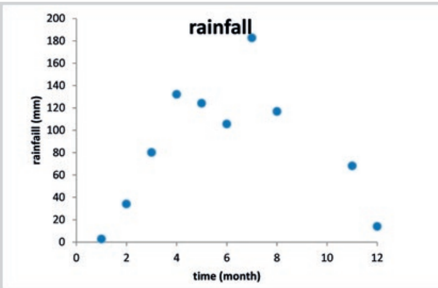
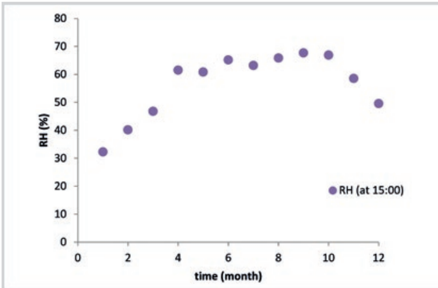


Figure 18. *Long-term climate characters for Wenchi and Tamale*

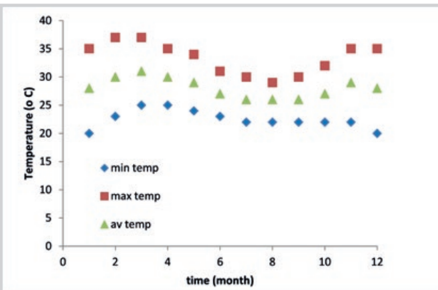
Wenchi







Tamale



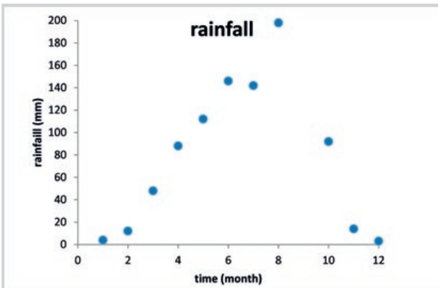
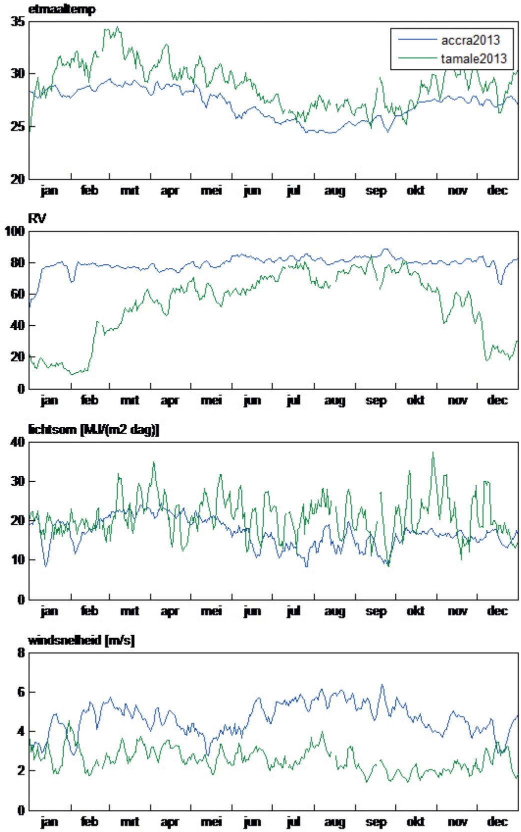


Figure 19. *Long-term climate characters for Accra and Tamale*



Annex 5. Cost–Benefit Scenarios

SCENARIO 1 all amounts in €

	Cash flow analysis	2014	2015	2016	2017	2018	2019
1	**Turnover (€)**	**3,000**	**3,450**	**3,968**	**4,563**	**5,247**	**6,034**
	quantity tomatoes (kg)	4,800	4,800	4,800	4,800	4,800	4,800
	avarage price tomato (€/kg)	0.63	0.72	0.83	0.95	1.09	1.26
	total square meters	120	120	120	120	120	120
	yield (kg/m²)	40.00	40.00	40.00	40.00	40.00	40.00
2	**Cost of the product or service**	**750**	**863**	**992**	**1,141**	**1,312**	**1,509**
	– material costs: seeds, agrochemicals, fertilizer	300	345	397	456	525	603
	– labour costs	450	518	595	684	787	905
	– income owner	-	-	-	-	-	-
	– electricity	-	-	-	-	-	-
	– water	-	-	-	-	-	-
3	**Investment costs**	**4,444**	**-**	**-**	**-**	**-**	**-**
	greenhouse + installation (€)	4,444	-	-	-	-	-
	bore hole + solar panel + pump	-	-	-	-	-	-
3a	outstanding bank loan	4,444	4,444	2,963	1,481	-	-
4	**Fixed costs**	**1,422**	**1,449**	**1,065**	**685**	**311**	**358**
	maintenance	178	204	235	270	311	358
	interest	1,244	1,244	830	415	-	-
4a	Depriciation	667	667	667	667	667	667
5	**Cash flow from operations**	2,372-	2,383	2,741	3,152	3,624	4,168
	subsidies	-	-	-	-	-	-
	capital payment bank	-	1,481	1,481	1,481	-	-
	interest bank loan	1,244	1,037	622	207	-	-
	Cash flow after capital payment and interest	**3,617-**	**135-**	**637**	**1,463**	**3,624**	**4,168**
6	**Cumulative cash flow after capital payment and interest**	**3,617-**	**3,752-**	**3,115-**	**1,653-**	**1,972**	**6,140**
7a	**Cumulative profits**	3,000	6,450	10,418	14,980	20,227	26,261
7b	**Cumulative costs (including depreciation)**	2,839	5,817	8,540	11,033	13,322	15,855
7c	**Cumulative net profit**	**161**	**633**	**1,877**	**3,947**	**6,905**	**10,406**

SCENARIO 2 all amounts in €

	Cash flow analysis	2014	2015	2016	2017	2018	2019
1	**Turnover (€)**	**5,400**	**6,210**	**7,142**	**8,213**	**9,445**	**10,861**
	quantity tomatoes (kg)	4,800	4,800	4,800	4,800	4,800	4,800
	avarage price tomato (€/kg)	1.13	1.29	1.49	1.71	1.97	2.26
	total square meters	120	120	120	120	120	120
	yield (kg/m²)	40.00	40.00	40.00	40.00	40.00	40.00
2	**Cost of the product or service**	**750**	**863**	**992**	**1,141**	**1,312**	**1,509**
	– material costs: seeds, agrochemicals, fertilizer	300	345	397	456	525	603
	– labour costs	450	518	595	684	787	905
	– income owner	-	-	-	-	-	-
	– electricity	-	-	-	-	-	-
	– water	-	-	-	-	-	-
3	**Investment costs**	**4,444**	**-**	**-**	**-**	**-**	**-**
	greenhouse + installation (€)	4,444	-	-	-	-	-
	bore hole + solar panel + pump	-	-	-	-	-	-
3a	outstanding bank loan	4,444	4,444	2,963	1,481	-	-
4	**Fixed costs**	**1,422**	**1,449**	**1,065**	**685**	**311**	**358**
	maintenance	178	204	235	270	311	358
	interest	1,244	1,244	830	415	-	-
4a	Depriciation	667	667	667	667	667	667
5	**Cash flow from operations**	28	5,143	5,915	6,802	7,822	8,995
	subsidies	-	-	-	-	-	-
	capital payment bank	-	1,481	1,481	1,481	-	-
	interest bank loan	1,244	1,037	622	207	-	-
	Cash flow after capital payment and interest	**1,217-**	**2,625**	**3,811**	**5,113**	**7,822**	**8,995**
6	**Cumulative cash flow after capital payment and interest**	**1,217-**	**1,408**	**5,219**	**10,331**	**18,153**	**27,149**
7a	**Cumulative profits**	5,400	11,610	18,752	26,964	36,409	47,270
7b	**Cumulative costs (including depreciation)**	2,839	5,817	8,540	11,033	13,322	15,855
7c	**Cumulative net profit**	**2,561**	**5,793**	**10,211**	**15,931**	**23,087**	**31,415**

SCENARIO 3 all amounts in €

	Cash flow analysis	2014	2015	2016	2017	2018	2019
1	**Turnover (€)**	**3,000**	**3,450**	**3,968**	**4,563**	**5,247**	**6,034**
	quantity tomatoes (kg)	4,800	4,800	4,800	4,800	4,800	4,800
	avarage price tomato (€/kg)	0.63	0.72	0.83	0.95	1.09	1.26
	total square meters	120	120	120	120	120	120
	yield (kg/m²)	40.00	40.00	40.00	40.00	40.00	40.00
2	**Cost of the product or service**	**750**	**863**	**992**	**1,141**	**1,312**	**1,509**
	– material costs: seeds, agrochemicals, fertilizer	300	345	397	456	525	603
	– labour costs	450	518	595	684	787	905
	– income owner	-	-	-	-	-	-
	– electricity	-	-	-	-	-	-
	– water	-	-	-	-	-	-
3	**Investment costs**	**5,556**	**-**	**-**	**-**	**-**	**-**
	greenhouse + installation (€)	4,444	-	-	-	-	-
	bore hole + solar panel + pump	1,111	-	-	-	-	-
3a	outstanding bank loan	5,556	5,556	4,444	3,333	2,222	1,111
4	**Fixed costs**	**1,778**	**1,811**	**1,538**	**1,271**	**1,011**	**758**
	maintenance	222	256	294	338	389	447
	interest	1,556	1,556	1,244	933	622	311
4a	Depriciation	833	833	833	833	833	833
5	**Cash flow from operations**	3,528–	2,332	2,682	3,084	3,547	4,079
	subsidies	-	-	-	-	-	-
	capital payment bank	-	1,111	1,111	1,111	1,111	1,111
	interest bank loan	1,556	1,400	1,089	778	467	156
	Cash flow after capital payment and interest	**5,083–**	**179–**	**482**	**1,195**	**1,969**	**2,812**
6	**Cumulative cash flow after capital payment and interest**	**5,083–**	**5,263–**	**4,781–**	**3,586–**	**1,617–**	**1,195**
7a	**Cumulative profits**	3,000	6,450	10,418	14,980	20,227	26,261
7b	**Cumulative costs (including depreciation)**	3,361	6,868	10,232	13,477	16,633	19,733
7c	**Cumulative net profit**	**361–**	**418–**	**186**	**1,503**	**3,594**	**6,528**

SCENARIO 4 all amounts in €

	Cash flow analysis	2014	2015	2016	2017	2018	2019
1	**Turnover (€)**	**5,400**	**6,210**	**7,142**	**8,213**	**9,445**	**10,861**
	quantity tomatoes (kg)	4,800	4,800	4,800	4,800	4,800	4,800
	avarage price tomato (€/kg)	1.13	1.29	1.49	1.71	1.97	2.26
	total square meters	120	120	120	120	120	120
	yield (kg/m²)	40.00	40.00	40.00	40.00	40.00	40.00
2	**Cost of the product or service**	**750**	**863**	**992**	**1,141**	**1,312**	**1,509**
	– material costs: seeds, agrochemicals, fertilizer	300	345	397	456	525	603
	– labour costs	450	518	595	684	787	905
	– income owner	-	-	-	-	-	-
	– electricity	-	-	-	-	-	-
	– water	-	-	-	-	-	-
3	**Investment costs**	**5,556**	**-**	**-**	**-**	**-**	**-**
	greenhouse + installation (€)	4,444	-	-	-	-	-
	bore hole + solar panel + pump	1,111	-	-	-	-	-
3a	outstanding bank loan	5,556	5,556	4,167	2,778	1,389	-
4	**Fixed costs**	**1,778**	**1,811**	**1,461**	**1,116**	**778**	**447**
	maintenance	222	256	294	338	389	447
	interest	1,556	1,556	1,167	778	389	-
4a	Depriciation	833	833	833	833	833	833
5	**Cash flow from operations**	1,128–	5,092	5,856	6,734	7,744	8,906
	subsidies	-	-	-	-	-	-
	capital payment bank	-	1,389	1,389	1,389	1,389	-
	interest bank loan	1,556	1,361	972	583	194	-
	Cash flow after capital payment and interest	**2,683–**	**2,342**	**3,495**	**4,762**	**6,161**	**8,906**
6	**Cumulative cash flow after capital payment and interest**	**2,683–**	**341–**	**3,153**	**7,915**	**14,076**	**22,982**
7a	**Cumulative profits**	5,400	11,610	18,752	26,964	36,409	47,270
7b	**Cumulative costs (including depreciation)**	3,361	6,868	10,154	13,244	16,166	18,955
7c	**Cumulative net profit**	**2,039**	**4,742**	**8,598**	**13,721**	**20,243**	**28,315**

The GhanaVeg Program

GhanaVeg believes in healthy and quality vegetables from Ghana through new ways of doing business. GhanaVeg supports frontrunner companies in the vegetables sector with business information, contacts and can provide hands-on assistance in setting up or expanding your company.

Wageningen UR

Wageningen UR is a university and research centre in the Netherlands that focusses specifically on the theme 'healthy food and living environment'. Wageningen UR has a staff of 6,500 and 10,000 students from over 100 countries work everywhere around the world for governments and the business community-at-large.

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